Are Surface Shear-Stress Fluctuations a Valid Source of Sound?

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In aeroacoustics, a complete solution is possible only in rare instances. More often, one cautiously uses the acoustic analogy of Lighthill. In doing this, it is not always clear what to consider as a genuine source of sound and what to consider as a propagation effect. One way such a problem can arise is when the sources of sound cannot be separated from the effects of sound. For instance, it is well known that surface pressure fluctuations, which at first sight looked like a source of sound, actually represent only the reflection of sources located within the flow above the surface. Surface shear-stress fluctuations, the object of the present study, have posed a similar problem because sound propagating above the wall produces its own wall shear fluctuations in addition to those caused by the flow. Those who argue against shear-stress fluctuations being a valid source begin with the fact that only shear-stress fluctuations at the acoustic wavelength can radiate sound. These fluctuations, it is argued, must be a result of the sound itself. Therefore, shear-stress fluctuations are not a true source and provide merely a modification to the sound created by the flow. On the other hand, some investigators have boldly assumed that surface shear-stress fluctuations caused by the flow are a genuine source of dipole sound. Who is right?

Numerical simulation is useful in resolving such issues in the absence of analytical insight. A simple two-dimensional computational experiment was undertaken after modifying a code developed earlier by Mitchell and Lele (Stanford University, Stanford, California), which meets the stringent requirements of accurate aeroacoustic computations. A portion of a wall was oscillated tangentially. This does not prejudice the issue since (unlike normal motion) it is not by itself a source of sound. The first figure shows the sound field computed on a large enough domain to accommodate a few acoustic wavelengths. In comparison, the vortical flow created is in a tiny

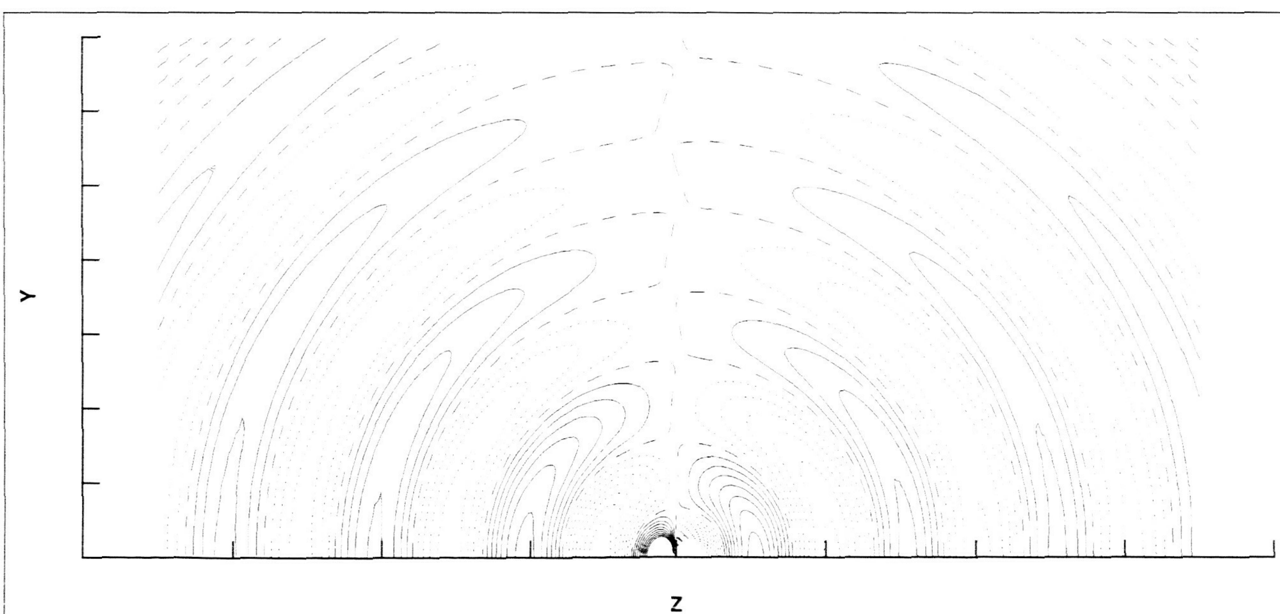

Fig. 1. Contours of acoustic pressure produced by a localized tangential wall oscillation.

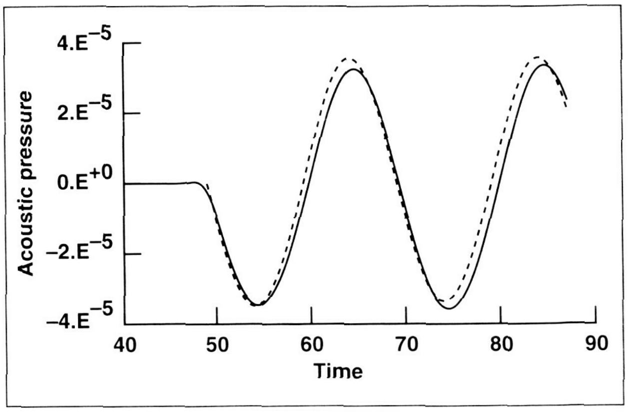

Fig. 2. Comparison of acoustic pressure in the simulation (solid) and a formulation (dashed) which regards surface shear-stress fluctuations as a valid source of sound.

region near the origin. The sound field is of dipole character. The second figure shows that the computed amplitude of the sound field (solid line) agrees with a formulation (dashed line) that regards shear-stress fluctuations as acoustically compact and as a genuine source of sound. The argument presented above, against shear-stress fluctuations being a valid source, fails because even at the acoustic wavelength, the flow itself evidently makes a larger contribution to the shear-stress spectrum.

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Aeronautics Design/Test Environment Phased Microphone Array Technology

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Noise has become a major driver in the design of aircraft. The development of low-noise aircraft within a rapid design-cycle process requires that the noise design be done concurrently with other disciplines such as high-lift aerodynamics and landing gear development. Phased Microphone Array Technology (PMAT), currently being developed as part of the Aeronautics Design/Test Environment effort to expand the role of the wind tunnel in the overall aircraft development process, shows great promise for attacking the noise design problem, as well as for being an instrumentation system that can be run concurrently with aerodynamic, performance, controls, and structural loads testing. Because it is nonintrusive, PMAT is compatible with optical measurement technologies that are being developed. Implementation of the array measurement capability will allow designers to evaluate the acoustic effect of design details in parallel with the aerodynamic development. This will result in a significant improvement in the present design-cycle process.

In classic acoustic testing, the result is generally a spectral plot from a single microphone. Although this is informative, it can be ambiguous, for the spectrum contains noise from the environment as well as the noise generated by the test object. PMAT allows researchers to reduce the effect of the background noise and to locate noise sources coming only from the item being tested. This level of detail from the array results shows true effects of parameter changes, while it also reduces the corruption of the signal from the background noise. The figure shows the reduced noise as seen in the spectral plots, but also allows the researcher to see the localized effects of installing the flap fences. This detailed information could not have been acquired without PMAT.

PMAT integrates several instrumentation, computer, and high-speed network systems to produce noise maps at specified frequencies. Sources of noise on aircraft and engine models are identified and isolated through computational analysis of the signals received from the microphone array. The signals are measured with a 100-element microphone array mounted in the wind tunnel and processed on a supercomputer. The current system has the capability of returning results for 200 frequencies within about